IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants	:	Jason Charles PELLY et al.
Serial No.	:	10/010,026
Filed	:	December 6, 2001
For	:	EMBEDDING DATA IN MATERIAL
Art Unit	:	2621

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Bruno Polito, Reg. No. 38,580
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February 7, 2002
Date of Signature

CLAIM OF PRIORITY

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

In support of the claim of priority under 35. U.S.C. § 119 asserted in the Declaration accompanying the above-entitled application, as filed, please find enclosed herewith certified copies of U.K. Application Nos. 0029865.3 and 0029869.5, filed in U.K. on 7 December 2000 and 7 December 2000, respectively, forming the basis for such claim.

Acknowledgment of the claim of priority and of the receipt of said certified copy(s) is requested.

Respectfully submitted,

FROMMER LAWRENCE & HAUG LLP
Attorneys for Applicants

By: _____
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Enclosure(s)

OIPE
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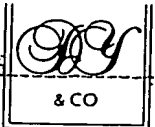
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The Patent Office

Cardiff Road
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1. Your reference	P010031GB RWP

2. Patent application number *(The Patent Office will fill in this part)*	7 DEC 2000	**0029865.3**

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	Sony United Kingdom Limited The Heights Brooklands Weybridge KT13 0XW United Kingdom
Patents ADP number *(if you know it)*	
If the applicant is a corporate body, give the country/state of its incorporation	UNITED KINGDOM
4. Title of the invention	Embedding Data in Material
5. Name of your agent *(if you have one)*	**D YOUNG & CO**
"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)	**21 NEW FETTER LANE** **LONDON** **EC4A 1DA**
Patents ADP number *(if you know it)*	**59006**

6. If you are declaring priority from one or more earlier patent applications, give the country and date of filing of the or each of these earlier applications and *(if you know it)* the or each application number	Country	Priority application number *(if you know it)*	Date of filing *(day/month/year)*
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7. If this application is divided or otherwise derived from an earlier UK application, give the number and filing date of the earlier application	Number of earlier application	Date of filing (day/month/year)

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b) there is an inventor who is not named as an applicant, or
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Claim(s)	6
Abstract	1
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Priority Documents	0
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Request for substantive examination *(Patents Form 10/77)*	0
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11.   I/We request the grant of a Patent on the basis of this application.

Signature   Date

D YOUNG & CO   7 Dec 2000
Agents for the Applicants

12. Name and daytime telephone number of person to contact in the United Kingdom

Richard Pratt   023 80719500
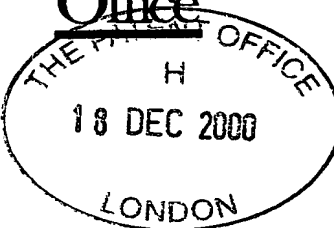
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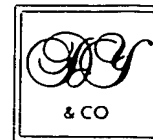
Statement of inventorship and of right to grant of a patent

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1.	Your reference	P010031GB RWP
2.	Patent application number *(if you know it)*	0029865.3
3.	Full name of the or of each applicant	SONY UNITED KINGDOM LIMITED
4.	Title of the invention	EMBEDDING DATA IN MATERIAL
5.	State how the applicant(s) derived the right from the inventor(s) to be granted a patent	BY VIRTUE OF AN ASSIGNMENT DATED 14 DECEMBER 2000.
6.	How many, if any, additional Patents Forms 7/77 are attached to this form? *(see note (c))*	

7.

I/We believe that the person(s) named over the page *(and on any extra copies of this forms)* is/are the inventor(s) of the invention which the above patent relates to.

Signature   Date

D YOUNG & CO   15 Dec 2000
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023 80634816   Richard Pratt

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Enter the full names, addresses and postcodes of the inventors in the boxes and underline the surnames

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Patents ADP number (if you know it): 407432-4/001

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Embedding Data in Material

The present invention relates to embedding data in material.

In this specification "material " means any one or more of video material, audio material and data material. 'Video' is generic to still and moving images.

5　Steganography

Steganography is the embedding of data into material such as video material, audio material and data material in such a way that the data is imperceptible in the material.

Data may be embedded as a watermark in material such as video material, 10　audio material and data material. A watermark may be imperceptible or perceptible in the material.

A watermark may be used for various purposes. It is known to use watermarks for the purpose of protecting the material against, or trace, infringement of the intellectual property rights of the owner(s) of the material. For example a watermark 15　may identify the owner of the material.

Watermarks may be "robust" in that they are difficult to remove from the material. Robust watermarks are useful to trace the provenance of material which is processed in some way either in an attempt to remove the mark or to effect legitimate processing such as video editing or compression for storage and/or transmission. 20　Watermarks may be "fragile" in that they are easily damaged by processing which is useful to detect attempts to remove the mark or process the material.

Visible watermarks are useful to allow e.g. a customer to view an image e,g. over the Internet to determine whether they wish to buy it but without allowing the customer access to the unmarked image they would buy. The watermark degrades the 25　image and the mark is preferably not removable by the customer. Visible watermarks are also used to determine the provenance of the material into which they are embedded.

It is known to embed data in material. It is desirable to do that and allow the data to be removed from the material to avoid degrading the material. It is known to 30　combine the data with the material, the data being scaled by a scaling factor which is

chosen according to desired properties of the data when combined with the material. Those properties include one or more of: concealing the data in the material; making the data perceptible in the material; making the data, when embedded in the material, resistant to processing which, intentionally and unintentionally, removes or damages

5   the embedded data.

According to a first aspect of the invention, there is provided a method of embedding data in material, the method comprising

combining a representation of the material with a function of the data and a scaling factor; wherein

10   the scaling factor is generated as a function of a trial decoding of the material, the trial decoding comprising processing the material to recover data therefrom.

Thus the scaling factor can be chosen on the basis of an estimate of the result of a process (e.g. decoding) which will be performed on the combined material and data in practice so as to increase the likelihood that the data is recoverable from the

15   material.

An embodiment of the invention further comprises the steps of:

combining, as a trial, a representation of the material with a function of the data and a trial scaling factor; and

performing, as a trial, a predetermined process on the combined material and data;

20   wherein the scaling factor is generated as a function of a trial decoding of the processed combined material and data.

Thus the scaling factor can be chosen on the basis of an estimate of the result of a process (e.g. JPEG processing) which could be performed on the combined material and data in practice and which may damage the embedded data, so as to

25   increase the likelihood that the data will not be damaged by such processing .

According to a further aspect of the invention, there is provided a method of embedding data in material, the method comprising the steps of:

producing transform coefficients C_i representing a transform of the material;

producing a pseudo random symbol sequence (PRSS) having L symbols P_i of

30   values +1 and -1;

calculating the correlation $S = \Sigma \, C_i.P_i$, for $i=1$ to $i=L$; and

calculating modified coefficient values $Ci' = Ci + \alpha * Pi$, where α is calculated dependent on S and the value of the data bit to be embedded in the coefficient.

Preferably

$$\alpha = (\alpha' + \text{offset})$$

where α' + offset is a function of the data bit to be embedded in the coefficient, and the method comprises the step of calculating modified coefficient values

$$Ci' = Ci + (\alpha' + \text{offset}) * Pi \text{ where}$$

$\alpha' = 0$ if S is positive and the data to be concealed is a bit of a first value,

$\alpha' = 0$ if S is negative and the data to be concealed is a bit of a second value,

and otherwise α' is a function of S such that $\Sigma\ Ci'.Pi$ has the correct sign to represent the bit to be encoded.

It will be noted that the calculation of the correlation $S = \Sigma\ Ci.Pi$, for i=1 to i=L is a form of trial decoding as in the said first aspect and the scaling factor is chosen in dependence on that correlation.

A further aspect of the invention provides a computer program product arranged to carry out one of the aforesaid methods when run on a computer.

The invention also provides corresponding apparatus in other aspects of the invention.

For a better understanding of the present invention, reference will now be made by way of example to the accompanying drawings in which:

Figure 1 is a schematic block diagram of an embodiment of a watermarking system according to the present invention;

Figure 2 is a schematic block diagram of another embodiment of a watermarking system according to the present invention;

Figure 3A is a schematic diagram of a wavelet transform showing the relationship of the symbols of a pseudo random symbol sequence to coefficients ;

Figure 3B is a flow diagram of calculations performed by the system of Figure 2;

Figure 4 is a schematic block diagram of an illustrative watermark decoding and removal system;

Figure 5 is a flow diagram of calculations performed by the watermark remover and decoder of Figure 4;

Figure 6 is a schematic block diagram of a further embodiment of a watermarking system according to the present invention;

Figures 7 to 10A are schematic block diagram of subsystems of the system of Figure 6;

Figures 10B and 10C are flow diagrams illustrating a process for calculating α;

Figures 11 and 12 are diagrams explaining wavelet transforms; and

Figures 13 and 14 are diagrams showing a UMID and a data reduced UMID.

Overview

Referring to Figure 1, in the shown illustrative watermarking system, a spatial domain image I produced by a source 1 is combined with watermark data Ri to produce a spatial domain watermarked image I'. The watermarked image is produced by an embedder 3 according to the equation

$$Ci'=Ci + \alpha. Ri$$

where Ci and Ci' are, for example, wavelet transform coefficients of the image, and α is a scaling factor which is also referred to herein as 'strength'. α is chosen in this example so that the watermark is imperceptible in the image and to resist removal of the watermark by unauthorised processing. It is thus desirable that α has the smallest value which achieves that. If α is too big the watermark is perceptible in the image; if it is too small the mark may not survive processing of the image.

-. In accordance with this embodiment, α is determined from a trial decoding of the original *unmarked* image I in a decoder 4. The decoding is that which would be used to decode the watermarked image I'. A value α' is produced by a calculator S3-S8, to which an offset value is added by an adder S9 to produce α. This produces values of α over the image, which are used to scale the data Ri so as to conceal the data.

Figure 2 shows an example of the system of Figure 1 in which the calculation of α also encodes Ri. Figure 6 shows an example of the system of Figure 1 in which the trial decoding takes place after a trial processing of the image data by a process which is likely to be applied to the watermarked image.

The data Ri in the examples given below is derived from a UMID. UMIDs are described in the section *UMIDs* below. As mentioned above, and in the examples given below, the image is subjected to a wavelet transform. Wavelet transforms are briefly discussed in the section *Wavelets* below.

5   Figure 2

Referring to Figure 2, for the purposes of explanation, it is assumed that the wavelet transform applied to the original spatial domain image results in a transform having four sub-bands of level 1: see the section *Wavelets* below. For ease of explanation the following description will refer only to the upper horizontal sub-band,

10   but it will be appreciated that the present invention can be applied to any sub-band and may be applied to a plurality of sub-bands. The coefficients of the wavelet transform are denoted by C_i where i is the ith coefficient of a sequence of JxL coefficients where there are J bits of UMID data W1 to WJ. As will become apparent the JxL coefficients correspond to symbols Pi of a Pseudo Random Symbol Sequence PRSS. Each UMID

15   bit is embedded in L wavelet coefficients.

In this example a UMID is produced as the watermark data by a UMID generator 6. In this example the watermark is imperceptible. The data of the UMID is combined with the wavelet coefficients C_i in an embedder 3 in the manner described in detail in the following text. The transformed image together with the watermark C_i'

20   is subjected to an inverse wavelet transform T^{-1}, (5) to produce a spatial domain watermarked image I'.

The watermark is decoded and, optionally, removed from the watermarked image using the illustrative decoding and removal system of Figure 4.

Trial decoder 4

25   A trial decoder 4 comprises a generator 4_1, a converter 4_2, and a correlator S1. The generator 4_1 produces a pseudo random binary sequence which is pseudo random because the sequence whilst appearing random can be reliably reproduced. The binary sequence has a length of JxL bits. The converter 4_2 converts the binary 1 and 0 to +1 and -1 respectively to produce a pseudo random symbol sequence (PRSS) Pi of values

30   +1 and -1. The symbols of the PRSS are denoted herein by Pi, where i denotes the ith symbol of the sequence which is JxL symbols along. The correlator produces correlation values

$S_j = \Sigma C_i.P_i$, where the sum is taken over the range $i = (j-1)L + 1$ to jL for each of $j=1$ to J.

Calculation of α_j and embedding the UMID

There is one strength value α_j for each UMID bit W_j.

The calculation of α_j and the embedding of the UMID in the image operates in accordance with the flow diagram of Figure 3B. The embedder 3 calculates a function

$$C_i' = C_i + \alpha_j P_i \qquad \text{for } i = (j-1)L + 1 \text{ to } jL \text{ for each of } j=1 \text{ to J.}$$

where C_i' is an ith wavelet coefficient modified to encoded a bit of watermarking data; and

α_j is the scaling factor, the value of which depends on:

a) the value 1 or 0 of a bit W_j of the UMID to be encoded in modified coefficient C_i'; and

b) the sign of the correlation value $S_j = \Sigma C_i.P_i$, for $i = (j-1)L + 1$ to jL for each of $j=1$ to J, produced by the trial decoder 4; and

c) the offset value, which is +/-1 in this example, so $\alpha_j = \alpha_j' + \text{offset}_j$.

The principle of operation is that a watermark bit $W_j=1$ is encoded as a positive correlation value and $W_j=0$ is encoded as a negative correlation value (or vice versa). α_j is chosen to ensure the value of a correlation $S_j' = \Sigma C_i'.P_i$ for $i = (j-1)L + 1$ to jL for each of $j=1$ to J, performed *at the decoder* has the correct sign to represent the value of bit W_j. If the correlation S_j performed at the encoder has the correct sign, then $\alpha_j' = 0$ otherwise α_j' is modified to ensure that the correlation $S_j' = \Sigma C_i'.P_i$ performed at the decoder has the correct sign.

Thus referring to Figures 2 and 3:-

A value $\alpha_j' = \alpha_j - \text{offset}_j$.

Step S1 (correlator S1 of Figure 2) calculates the correlation value $S_j = \Sigma C_i.P_i$, where the sum is taken over the range $i = (j-1)L + 1$ to jL for a sequence $i = (j-1)L + 1$ to jL of coefficients C_i and PRSS bits P_i. (Note that 'symbols' P_i have values +1 and -1 to ensure that bits of value 0 produced by the generator 4_1 contribute to the value of S_j.) Step S1 is a trial decoding with a trial value of $\alpha_j = 0$.

Step S2 determines whether the bit W_j of the UMID generated by generator 6 is 1 or 0. It will be appreciated that the bit W_j is in effect encoded over L coefficients. If W_j =1 then steps S3 to S5 and $S9^+$ are followed. These steps are implemented by blocks S3-S8 and S9 in figure 2.

5   Step S3 determines the sign of the correlation S_j. If the sign is positive and the bit W_j is 1 then

at step S4 α_j' =0.

If the sign determined at step S3 is negative but the bit W_j =1 (which should be encoded by S_j positive), then

10   at step S5 α_j'=-S_j/(L-1).

At step $S9^+$, the offset +1 is added to ensure that α_j is positive if S_j=0 and to increase robustness.. It should be noted that the offset is a signed value (+1) in this example.

If W_j=0 then steps S6 to S8 and $S9^-$ are followed. These steps are implemented
15   by blocks S3-S8 and S9 in figure 2.

Step S6 determines the sign of the correlation S_j. If the sign is negative and the bit W_j is 0 then

at step S7 α_j' =0.

If the sign determined at step S6 is positive but the bit W_j =0 (which should be
20   encoded by S negative), then

at step S8 α_j'=-S_j/(L-1).

-. At step $S9^-$ the offset -1 is added to ensure that α_j is negative if S_j=0 and to increase robustness. It should be noted that the offset is a signal value (-1) in this example.

25   At step S10 the value C_i' = C_i + α_j P_i is calculated for i = (j-1)L + 1 to jL.

The value α_j'=-S_j/(L-1) is an example. The value α_j' could be α_j'=-S_j/L as another example.

Watermark Decoding and Removing System (Figures 4 and 5)

Referring to Figure 4, the watermark removing and decoding system has an
30   input for receiving a spatial domain watermarked image I' from the system of Figure 1.

The image may have been subject to image processing (not shown) between production by the system of Figure 1 and the receipt by the system of Figure 4.

The received image is transformed by a wavelet transformer 46 (T) to produce wavelet coefficients Ci'. The coefficients Ci' are provided to a synchroniser 8 which correlates the coefficients with a PRSS generated by a generator 10. The synchroniser 8 and the PRSS 10 carry out, in known manner, correlations with differing shifts of the PRSS relative to the coefficients to determine the position in the watermarked transformed image of the original PRSS produced at the watermarking system of Figure 1. Once synchronisation has been achieved the coefficients Ci' are correlated with the PRSS in another correlator 12 to produce the correlation value

$$Sj' = \Sigma Ci'.Pi \text{ for } i = (j-1)L + 1 \text{ to } jL \text{ for each of } j=1 \text{ to } J.$$

where Pi has values +1 and -1.

The correlation value Sj' is provided to a decoder 14 and to a remover 16, the operations of which will be described with reference to the flow diagram of Figure 5. The decoder 14 extracts the UMID from the image. The watermark is removed by the remover 16. The resulting restored transformed image is subject to an inverse wavelet transform (T^{-1}) in an inverse transformer 18.

Referring to Figure 5, the synchronisation of the PRSS with the received transformed image occurs at step S12. At step S14, the correlation value

$$Sj' = \Sigma Ci'.Pi \text{ for } i = (j-1)L + 1 \text{ to } jL.$$

is calculated over a length L of the PRSS.

At step S16, the sign of the value Sj' is determined. If Sj' is negative then the bit of the watermark, (the UMID in this example), is 0. If Sj' is positive the bit of the watermark is 1.

At step S18,

$$\alpha j = Sj'/(L-1)$$

is calculated from Sj'. (This calculation may be an approximation because it assumes that $\Sigma Ci.Pi =0$)

At step S22, $Ci = Ci' - \alpha j Pi$ is calculated for . $i = (j-1)L + 1 \text{ to } jL.$

If, in the embedding process, αj is calculated as $-\dfrac{Sj}{L}$ at the step S5 or S8, then

in the decoding process $\alpha j'$ is calculated as Sj'/L at step S18.

Modifications.

a). Threshold on the values of Ci

In a modification of the embodiment described above, the values of the

coefficients Ci are compared with a threshold value Th_e at the embedder of Figure 1,

and the values of the coefficients Ci' are compared with a threshold value Th_d. at the

remover 16 of Figure 4 and also at the decoder 14 of Figure 4. If the value of a

coefficient exceeds the threshold, that coefficient is not used in establishing the

correlation value Sj or Sj'. Th_e and Th_d may be equal, but it has been found that Th_d is

preferably greater than Th_e.

By way of a simple example, assume that the PRSS has length L=4 and

symbols P1 to P4 have values +1, -1,-1, and +1. Then referring to Table 1 three

examples are shown.

	P1 C1	P2 C2	P3 C3	P4 C4	Sj, αj' Wj=0
Pi	+1	-1	-1	+1	
Ex1 Ci	-2	-5	+1	-3	-1, 0
Ex2 Ci	-2	-25	+1	-3	+19, -6.3
Ex3 Ci	-2		+1	-3	-6, 0

Table 1

Example 1 (Ex1)

The coefficients Ci have values shown. If the value of the bit Wj of the

watermark to be encoded is 0 then according to Figure 3, Sj=-1 and so $\alpha j'$ =0.

Example 2 (Ex2)

However if as shown in example 2 the coefficient C2 has a value -25 than

Sj=+19 and $\alpha j'$=-6.3. Large values of $\alpha j'$ may cause the watermark to be perceptible

when it should be imperceptible.

Example 3 (Ex3)

In accordance with an embodiment of the present invention, a threshold Th_e is set. It may be about 6 for the above example. In practice it is set empirically. Thus as shown in Table 1, the coefficient C2 is not used in the calculation of Sj, and also the corresponding bit of the PRSS is also not used. As a result $Sj=-6$ and $\alpha j'=0$.

b) Clipping coefficient values.

In an alternative modification, the values of the modified coefficients Ci' are clipped at the decoder of Figure 4 if they exceed a threshold value Th_d. Thus coefficient values greater than the threshold are reduced to a predetermined value e.g. Th_d. For example referring to Table 1 Example 3, the coefficient C2 is clipped to say $Th_d=-6$ at the decoder.

Such clipping is also performed at the embedder of Figure 2.

Limiting α'

The value of α' may be limited to be within a present range determined by upper and lower bounds.

Trial processing and decoding- Figure 6

Referring to Figure 6, an unmarked spatial domain Image I is applied to an embedder 60. An example of the embedder is shown in Figure 8. The embedder calculates

$$Ci'' = Ci + \alpha_{Tj} Ri \text{ for } i = (j-1)L + 1 \text{ to } jL \text{ for each of } j=1 \text{ to } J.$$

where: Ci is a wavelet transform coefficient of the image; Ri is a watermarking symbol formed by combining a PRSS of JxL bits Pi with watermark data Wj. Symbol Ri has a value + or - 1; α_{Tj} is a trial value of the scaling factor for UMID (or watermark) data bit Wj. In this example $\alpha_{t,j}$ is initialised to 1. Figure 7 shows an example of a subsystem, for producing Ri.

The embedder also includes an inverse transformer which produces a spatial domain watermarked image Iw.

The image Iw is processed by a processor 62 to produce a processed spatial domain image Ip. The processor 62 is chosen to process the image according to a process which the watermarked image is likely to encounter in use, and/or a process which may be applied to the image to deliberately remove or damage the watermark.

JPEG processing using DCT transforms is a process which is known to be potentially damaging to some watermarks.

A decoder 64, an example of which is shown in Figure 9, decodes the processed image Ip. The decoder may extract the watermark data Wj. The decoder produces correlation values

$$Sip,j' = \Sigma Cip.Pi \text{ for } i = (j-1)L + 1 \text{ to } jL \text{ for each of } j=1 \text{ to } J.$$

where Cip are wavelet coefficients of the processed image Ip and the sum is calculated over a length L of a PRSS having JxL bits Pi.

A calculator 66 calculates a new value of αj based on the magnitude of Sip,j to produce new trial values of $\alpha_{t+n,j}$ which is used as a new value in the trial embedder 60. n is the number of iterations used to calculate a final value $\alpha_{t+n,j}$ which is applied to an embedder 69. n = 0,1,2. Several iterations may be used. Preferably the number of iterations is limited to a predetermined number, e.g. 4, because the process 62 may be non-linear (JPEG processing is non-linear) and it is then unlikely that the iterations will converge to steady values of $\alpha t,j$.

Examples of (a) the calculator 66 and (b) the embedder 69 are shown in Figures 10 and 8 respectively.

Calculating Ri, Figure 7.

A PRSS generator 71 produces a PRSS having JxL bits Pi. A UMID generator 72 produces a UMID having bits Wj. In a modulator 73, each bit Wj of the UMID modulates, and is thus spread over, an L bit sequence of the PRSS. A data converter 74 converts the binary values 1 and 0 at the output of the modulator to produce symbols Ri of value +1 and -1 respectively.

Embedder 60 and 69,- Figure 8.

The embedder of Figure 8 comprises a wavelet transformer 82 which produces the wavelet coefficients Ci and an inverse transformer 85. A multiplier 84 calculates $\alpha_{t+n,j}.Ri$. An adder 83 adds $\alpha_{t+n,j}.Ri$ to Ci to produce.

$$Ci' = Ci + \alpha_{t+n,j}.Ri \text{ for } i = (j-1)L + 1 \text{ to } jL \text{ for each of } j=1 \text{ to } J.$$

Thus each coefficient C_i is modified by a value of α associated with that coefficient and by one symbol R_i.

Unlike the example of Figures 2 and 3, R_i is a symbol stream comprising the PRSS modulated by the data to be embedded, and α is an unsigned magnitude.

5   Decoder 64-Figure 9

The decoder has a wavelet transformer 91 which produces wavelet coefficients C_{ip} from the processed image I_p. A synchroniser 92 operating in known manner shifts the phase of the PRSS produced by a PRSS generator 93 so that it is in phase with the PRSS in the image I_p. A data converter 94 converts the PRSS values P_i to +1 and -1.

10   A correlator calculates a correlation value

$$S_{ip,j} = \Sigma C_{ip}.P_i \quad i = (j-1)L + 1 \text{ to } jL \text{ for each of } j=1 \text{ to } J.$$

A decoder 96 determines the values of the data bits W_j from the sign of the correlation values $S_{ip,j}$.

15   Calculating α-Figures 10A, 10B and 10C

Referring to Figure 10A, new values of $\alpha_{t+1,j}$ are calculated by adding an offset to a basic fixed value $\alpha_{t,j}$ in an adder 99. The offsets are produced by an offset generator 95. The generator responds to an offset control value produced by a processor 97. The processor controls the offset and thus the values of $\alpha_{t+1,j}$ in

20   dependence on the correlation values $S_{ip,j}$.

Figures 10B and 10C illustrate examples of the operation of the processor.

-. Referring to Figure 10B, the correlation values $S_{ip,j}$ are compared at step S30 with the corresponding symbols W_j. The correlation values $S_{ip,j}$ are positive and negative, a positive value indicates a symbol 1 and a negative value a symbol 0, (if the

25   values S_{ip} are unchanged by the processing in processor 62).. If the signs of. $S_{ip,j}$ correctly represent W_j then the magnitude of $S_{ip,j}$ is compared with an upper threshold Th. If $|S_{ip,j}| > $Th then the value of α_j is reduced for the next iteration $\alpha_{t+1,j}$. If $|S_{ip,j}|$ is not greater than the threshold α_j either remains unchanged for the next iteration $\alpha_{t+1,j}$ or is used as the final value of $\alpha_{t,j}$.

30   If the sign of $S_{ip,j}$ indicates the incorrect value for W_j, then α_j is increased for the next iteration $\alpha_{t+1,j}$.

Referring to Figure 10C, at step S40 a value (Sip,j)/L is calculated from Sip,j. That is the average correlation value over L symbols. That value is used as $\alpha_{t+1,j}$ for the next iteration. Preferably $\alpha_{t+1,j}$ is compared with an upper threshold Th at step S42. If $\alpha_{t+1,j}$ exceeds Th, then $\alpha_{t+1,j}$ is reduced. Otherwise it is compared (S46) with a lower

5   threshold TL. If $\alpha_{t+1,j}$ is less than TL, $\alpha_{t+1,j}$ is increased (S48) otherwise it is unchanged (S49).

Modifications.

Other transforms

Whilst the invention has been described by way of example with reference to

10   Wavelet transforms, it may be used with other transforms for example DCT.

Other material

Whilst the invention has been described by way of example with reference to material comprising images, e.g. video material , it may be applied to other material, for example audio material and data material.

15   Other Watermark data.

Whilst the invention has been described by way of example with reference to UMIDs as the watermark data, it may be used with other data as the watermark.

Wavelets

Wavelets are well known and are described in for example " A Really Friendly Guide to Wavelets " by C Valens, 1999 and available at
5   http://perso.wanadoo.fr/polyvalens/clemens/wavelets/wavelets.html.

Valens shows that the discrete wavelet transform can be implemented as an iterated filter bank as used in sub-band coding, with scaling of the image by a factor of 2 at each iteration.

Thus referring to Figure 12, a spatial domain image is applied to a set of high
10   pass HP and low pass LP filters. At level 1, the first stage of filtering, the image is filtered horizontally and vertically and, in each direction, scaled down by a factor of 2. In level 2, the low pass image from level 1 is filtered and scaled in the same way as in level 1. The filtering and scaling may be repeated in subsequent levels 3 onwards.

The result is shown schematically in Figure 11. Figure 11 is a representation
15   normal in the art. At level one the image is spatially filtered into four bands: the lower horizontal and vertical band, lH_1, lV_1; the upper horizontal band hH_1, lV_1; the upper vertical band lH_1, hV_1; and the upper horizontal and vertical band, hH_1, hV_1. At level 2, the lower horizontal and vertical band, lH_1, lV_1 is filtered and scaled into the lower horizontal and vertical band, lH_2, lV_2; the upper horizontal band hH_2, lV_2; the upper
20   vertical band lH_2, hV_2; and the upper horizontal and vertical band, hH_2, hV_2. At level 3 (not shown in Figure 11), the lower horizontal and vertical band, lH_2, lV_2 is further filtered and scaled.

UMIDs

The UMID or Unique Material Identifier is described in SMPTE Journal March 2000. Referring to Figure 13, an extended UMID is shown. It comprises a first set of 32 bytes of basic UMID and a second set of 32 bytes of signature metadata.

5   The first set of 32 bytes is the basic UMID. The components are:

•A 12-byte Universal Label to identify this as a SMPTE UMID. It defines the type of material which the UMID identifies and also defines the methods by which the globally unique Material and locally unique Instance numbers are created.

•A 1-byte length value to define the length of the remaining part of the UMID.

10   •A 3-byte Instance number which is used to distinguish between different 'instances' of material with the same Material number.

•A 16-byte Material number which is used to identify each clip. Each Material number is the same for related instances of the same material.

The second set of 32 bytes of the signature metadata as a set of packed

15   metadata items used to create an extended UMID. The extended UMID comprises the basic UMID followed immediately by signature metadata which comprises:

•An 8-byte time/date code identifying the time and date of the Content Unit creation.

•A 12-byte value which defines the spatial co-ordinates at the time of Content

20   Unit creation.

•3 groups of 4-byte codes which register the country, organisation and user codes.

Each component of the basic and extended UMIDs will now be defined in turn.

The 12-byte Universal Label

The first 12 bytes of the UMID provide identification of the UMID by the registered string value defined in table 1.

Byte No.	Description	Value (hex)
1	Object Identifier	06h
2	Label size	0Ch
3	Designation: ISO	2Bh
4	Designation: SMPTE	34h
5	Registry: Dictionaries	01h
6	Registry: Metadata Dictionaries	01h
7	Standard: Dictionary Number	01h
8	Version number	01h
9	Class: Identification and location	01h
10	Sub-class: Globally Unique Identifiers	01h
11	Type: UMID (Picture, Audio, Data, Group)	01, 02, 03, 04h
12	Type: Number creation method	XXh

5

Table 1: Specification of the UMID Universal Label

The hex values in table 1 may be changed: the values given are examples. Also the bytes 1-12 may have designations other than those shown by way of example in the table. Referring to the Table 1, in the example shown byte 4 indicates that bytes

10   5-12 relate to a data format agreed by SMPTE. Byte 5 indicates that bytes 6 to 10 relate to "dictionary" data. Byte 6 indicates that such data is "metadata" defined by bytes 7 to 10. Byte 7 indicates the part of the dictionary containing metadata defined by bytes 9 and 10. Byte 10 indicates the version of the dictionary. Byte 9 indicates the class of data and Byte 10 indicates a particular item in the class.

15   In the present embodiment bytes 1 to 10 have fixed preassigned values. Byte 11 is variable. Thus referring to Figure 14, and to Table 1 above, it will be noted that the bytes 1 to 10 of the label of the UMID are fixed. Therefore they may be replaced by a 1 byte 'Type' code T representing the bytes 1 to 10. The type code T is followed

by a length code L. That is followed by 2 bytes, one of which is byte 11 of Table 1 and the other of which is byte 12 of Table 1, an instance number (3 bytes) and a material number (16 bytes). Optionally, the material number may be followed by the signature metadata of the extended UMID and/or other metadata.

5   The UMID type (byte 11) has 4 separate values to identify each of 4 different data types as follows:

'01h' = UMID for Picture material

'02h' = UMID for Audio material

'03h' = UMID for Data material

10   '04h' = UMID for Group material (i.e. a combination of related essence).

The last (12th) byte of the 12 byte label identifies the methods by which the material and instance numbers are created. This byte is divided into top and bottom nibbles where the top nibble defines the method of Material number creation and the bottom nibble defines the method of Instance number creation.

15   **Length**

The Length is a 1-byte number with the value '13h' for basic UMIDs and '33h' for extended UMIDs.

Instance Number

The Instance number is a unique 3-byte number which is created by one of

20   several means defined by the standard. It provides the link between a particular 'instance' of a clip and externally associated metadata. Without this instance number, all material could be linked to any instance of the material and its associated metadata.

The creation of a new clip requires the creation of a new Material number together with a zero Instance number. Therefore, a non-zero Instance number

25   indicates that the associated clip is not the source material. An Instance number is primarily used to identify associated metadata related to any particular instance of a clip.

Material Number

The 16-byte Material number is a non-zero number created by one of several

30   means identified in the standard. The number is dependent on a 6-byte registered port ID number, time and a random number generator.

Signature Metadata

Any component from the signature metadata may be null-filled where no meaningful value can be entered. Any null-filled component is wholly null-filled to clearly indicate a downstream decoder that the component is not valid.

The Time-Date Format

5   The date-time format is 8 bytes where the first 4 bytes are a UTC (Universal Time Code) based time component. The time is defined either by an AES3 32-bit audio sample clock or SMPTE 12M depending on the essence type.

The second 4 bytes define the date based on the Modified Julian Data (MJD) as defined in SMPTE 309M. This counts up to 999,999 days after midnight on the 17th

10   November 1858 and allows dates to the year 4597.

The Spatial Co-ordinate Format

The spatial co-ordinate value consists of three components defined as follows:

•Altitude: 8 decimal numbers specifying up to 99,999,999 metres.

•Longitude: 8 decimal numbers specifying East/West 180.00000 degrees (5

15   decimal places active).

•Latitude: 8 decimal numbers specifying North/South 90.00000 degrees (5 decimal places active).

The Altitude value is expressed as a value in metres from the centre of the earth thus allowing altitudes below the sea level.

20   It should be noted that although spatial co-ordinates are static for most clips, this is not true for all cases. Material captured from a moving source such as a camera mounted on a vehicle may show changing spatial co-ordinate values.

Country Code

The Country code is an abbreviated 4-byte alpha-numeric string according to

25   the set defined in ISO 3166. Countries which are not registered can obtain a registered alpha-numeric string from the SMPTE Registration Authority.

Organisation Code

The Organisation code is an abbreviated 4-byte alpha-numeric string registered with SMPTE. Organisation codes have meaning only in relation to their registered

30   Country code so that Organisation codes can have the same value in different countries.

User Code

The User code is a 4-byte alpha-numeric string assigned locally by each organisation and is not globally registered. User codes are defined in relation to their registered Organisation and Country codes so that User codes may have the same value in different organisations and countries.

5

CLAIMS

1.   A method of embedding data in material, the method comprising combining a representation of the material with a function of the data and a scaling factor; wherein

5   the scaling factor is generated as a function of a trial decoding of the material, the trial decoding comprising processing the material to recover data therefrom.

2.   A method according to claim 1, wherein the step of combining involves modulating a pseudo random symbol sequence with the said data and the trial

10   decoding comprises the step of correlating a pseudo random symbol sequence with the said representation of the material, and the scaling factor is generated in dependence on the result of the correlation.

3.   A method according to claim 1 or 2, further comprising:

15   combining, as a trial, a representation of the material with a function of the data and a trial scaling factor; and

performing, as a trial, a predetermined process on the combined material and data;

wherein the scaling factor is generated as a function of a trial decoding of the

20   processed combined material and data.

4.   A method of embedding data bits in material, the method comprising the steps of:

producing transform coefficients C_i representing a transform of the material;

25   producing a pseudo random symbol stream having L symbols P_i of values +1 and -1;

calculating a correlation $S = \Sigma\ C_i.P_i$, for $i=1$ to $i=L$; and

calculating modified coefficient values $C_i' = C_i + \alpha * P_i$, where α is calculated dependent on S and the value of the data bit to be embedded in the coefficient.

30

5.   A method according to claim 4 wherein

$$\alpha = (\alpha' + \text{offset})$$

where α' + offset is a function ot the data bit to be embedded in the coefficient,

$\alpha' = 0$ if S is positive and the data to be concealed is a symbol of a first value,

$\alpha' = 0$ if S is negative and the data to be concealed is a symbol of a second value, and

otherwise α' is a function of S such that Σ Ci'.Pi has the correct sign to represent the symbol to be encoded.

6.   A method according to claim 5, wherein the first value is "1" and the second value is "0".

7.   A method according to claim 4, 5 or 6 wherein the said function of S is $\alpha' = - S/(L-1)$ or $\alpha' = - S/L$.

8.   A method according to claim 4, 5, 6 or 7, wherein the magnitude of the offset is greater than or equal to zero.

9.   A method according to claim 8, wherein the magnitude of the offset is one.

10.   A method according to any preceding claim, wherein the said coefficients are coefficients of a wavelet transform of the material.

11.   A method according to any preceding claim wherein the data to be embedded includes a UMID.

12.   A method of removing data from material, which data has been embedded by the method of any one of claims 4 to 11, the method comprising the steps of:

calculating the correlation S'=Σ Ci'*Pi for i=1 to L where Pi are the bits of the PRSS and have values +1 and -1;

calculating α_r as a function of S'; and

calculating $Ci=Ci'-\alpha_r.Pi$ to recover the unmodified coefficients Ci.

13.   A method according to claim 12, wherein $\alpha_r=S'/(L-1)$ or $\alpha_r=(S'/L)$.

14.   A method according to claim 12 or 13, further comprising deriving the symbols of the concealed data from S', where if S' is positive a symbol is of the first value and if S' is negative a symbol is of the second value.

15.   A method according to claim 12, 13 or 14, comprising the step of generating and synchronizing a reference pseudo random symbol sequence with the pseudo random symbol sequence of the embedded data.

16.   A computer program product arranged to carry out the method of any preceding claim when run on a computer.

17.   Apparatus for embedding data in material, the apparatus comprising:
a combiner for combining a representation of the material with a function of the data and a scaling factor;
a decoder for decoding, as a trial, the material to recover data therefrom; and
a generator for generating the scaling factor as a function of the trial decoding of the material.

18.   Apparatus according to claim 17, wherein:
the combiner includes a modulator for modulating a pseudo random symbol sequence with the said data;
the trial decoder comprises a correlator for correlating the pseudo random binary sequence with the said material; and
the scaling factor generator is arranged to generate the scaling factor in dependence on the result of the correlation.

19.   Apparatus according to claim 17 or 18, wherein the combiner is arranged to combine, as a trial, a representation of the material with a function of the data and a trial scaling factor;

and further comprising:

5   a processor for performing, as a trial, a predetermined process on the combined material and data;

wherein the scaling factor is generated as a function of a trial processing of the processed combined material and data so as to recover the said data.

10   20.   Apparatus for embedding data in material, the apparatus comprising:

a transformer for producing transform coefficients C_i representing a transform of the material;

a generator for producing a pseudo random symbol stream having L bits P_i;

an input for receiving symbol representing the data to be concealed; and

15   a data embedder arranged to

calculate a correlation $S = \Sigma\ C_i * P_i$, for i=1 to i=L and

calculate modified coefficient values $C_i' = C_i + \alpha * P_i$, where α is calculated dependent on S and the value of the data bit to be embedded in the coefficient.

20   21.   Apparatus according to claim 20 wherein

$$\alpha = (\alpha' + \text{offset})$$

where α' + offset is a function ot the data bit to be embedded in the coefficient, and the apparatus is arranged to

calculate modified coefficient values $C_i' = C_i + (\alpha' + \text{offset}) * P_i$ where

25    $\alpha' = 0$ if S is positive and the data to be concealed is a bit of a first value,

$\alpha' = 0$ if S is negative and the data to be concealed is a bit of a second value, and

otherwise α' is a function of S such that $\Sigma\ C_i'.P_i$ has the correct sign to represent the bit to be encoded.

30

22.   Apparatus according to claim 21, wherein the first value is "1" and the second value is "0".

23.   Apparatus according to claim 21 or 22 wherein $\alpha = -S/(L-1)$ or $-S/L$

24.   Apparatus according to claim 20, 21, 22 or 23, wherein the offset is greater than or equal to zero.

25.   Apparatus according to claim 25 wherein the offset = 1.

26.   Apparatus according to ant one of claims 20 to 25, wherein the coefficients are coefficients of a wavelet transform of the material.

27.   Apparatus according to any one of claims 19 to 24 comprising a generator for generating a UMID as the said data to be concealed.

28.   Apparatus for removing data from material, which data has been concealed by the apparatus of any one of claims 20 to 27, the apparatus comprising:

a generator for generating a PRSS; and

a calculator for calculating

the correlation $S' = \Sigma\, C_i'.P_i$ for $i = 1$ to L where P_i are the bits of the PRSS,

a value α_r dependent on S', and

a coefficient value $C_i = C_i' - \alpha_r.P_i$ to recover the unmodified coefficients C_i.

29.   Apparatus according to claim 26, wherein $\alpha_r = S/(L-1)$ or (S/L).

30.   Apparatus according to claim 28 or 29, further comprising a decoder for deriving the bits of the concealed data from the correlation value S', where if S' is positive a bit of the data has a first value and if S' is negative a bit of the data has a second value.

31   Apparatus according to claim 28, 29 or 30, comprising a synchronizer for synchronizing the generated PRSS with the PRSS of the embedded data.

33.   A method of embedding data in material substantially as hereinbefore
5   described with reference to anyone of Figures 1 to 3 and 6 to 10 of the accompanying drawings.

33.   Apparatus for embedding data in material substantially as hereinbefore described with reference to anyone of Figures 1 to 3 and 6 to 10 of the accompanying
10   drawings.

---

34.   A method of removing data embedded in material substantially as hereinbefore described with reference to Figures 4 and 5 of the accompanying drawings.

15

35.   Apparatus for removing data embedded in material substantially as hereinbefore described with reference to Figures 4 and 5 of the accompanying drawings.

ABSTRACT

EMBEDDING DATA IN MATERIAL

A spatial domain image I produced by a source 1 is combined with watermark data Ri to produce a spatial domain watermarked image I'. The watermarked image is

5   produced by an embedder 3 according to the equation

$$C_i' = C_i + \alpha . R_i$$

where C_i and C_i' are wavelet transform coefficients of the image, and α is a scaling factor. α is chosen so that the watermark is imperceptible in the image and to resist removal of the watermark by unauthorised processing. It is desirable that α has

10   the smallest value which achieves that. If α is too big the watermark is perceptible in the image; if it is too small the mark may not survive processing of the image.

α is determined from a trial decoding of the image I in a decoder 4. The decoding is that which would be used to decode the watermarked image I'. A value α' is produced by a calculator S3-S8, to which an offset value is added by an adder S9 to

15   produce α. This produces values of α over the image, which are used to scale the data Ri so as to conceal the data. An image is one example of material to which the invention is applicable.

20   **[Figure 1]**
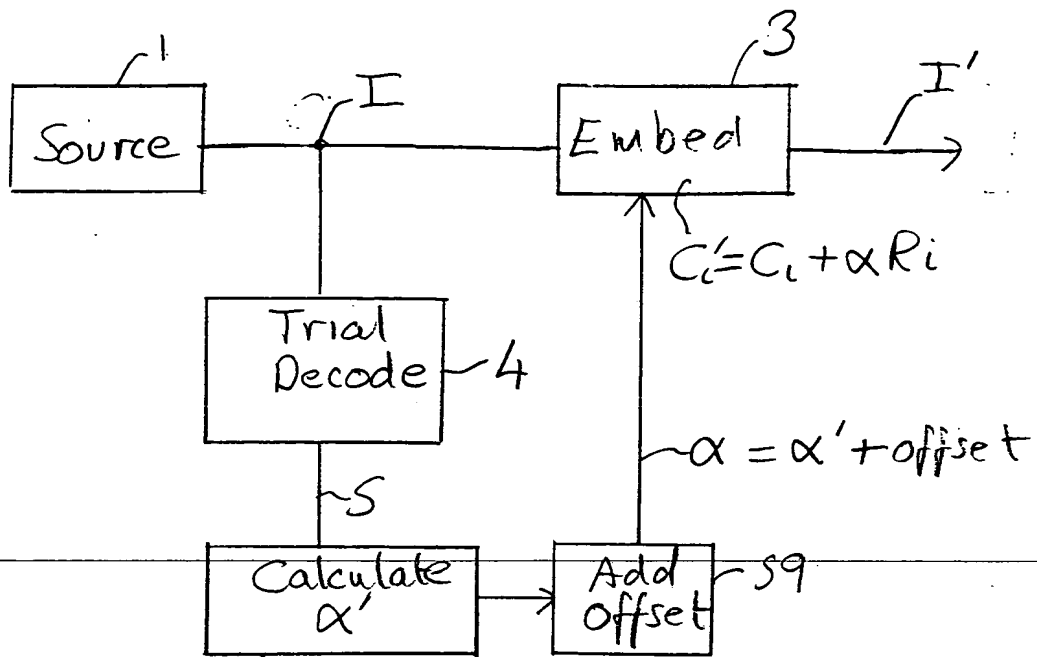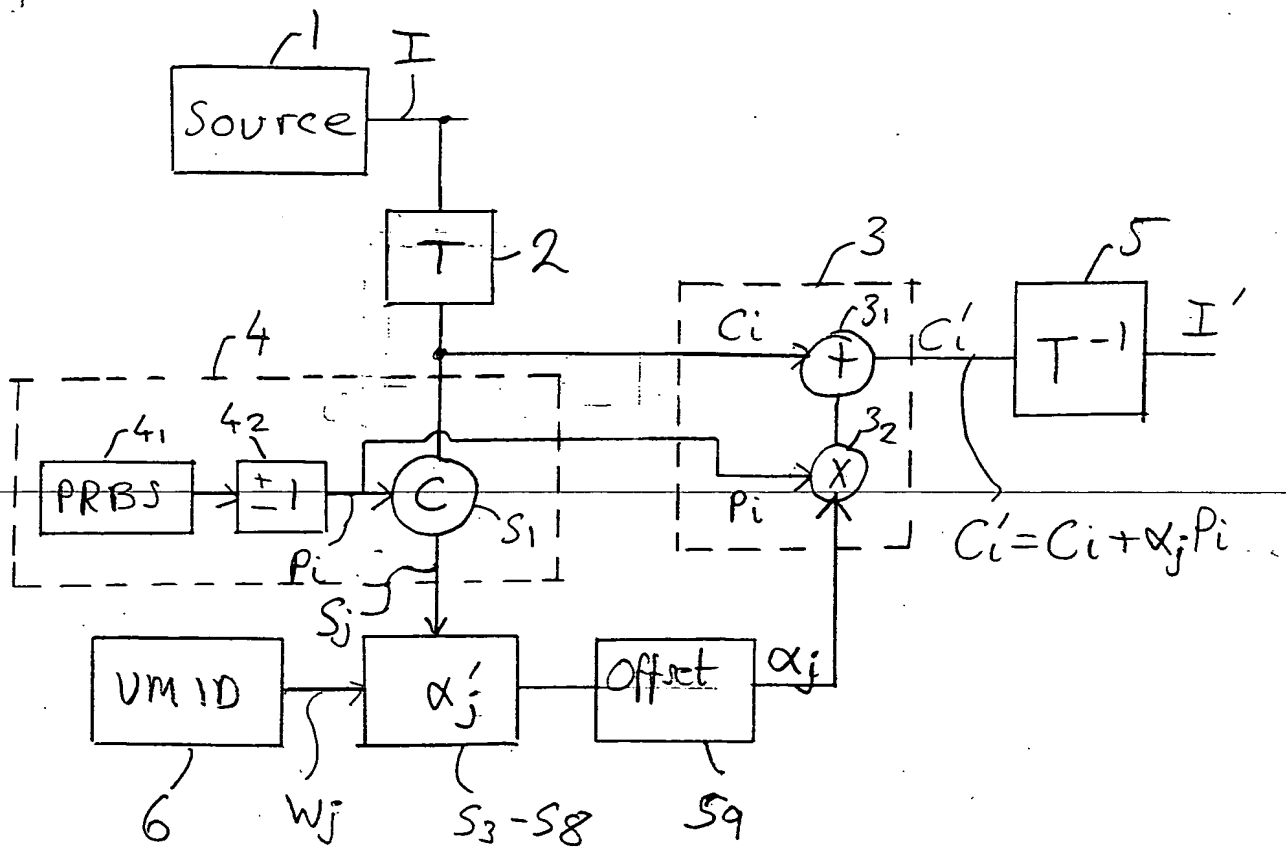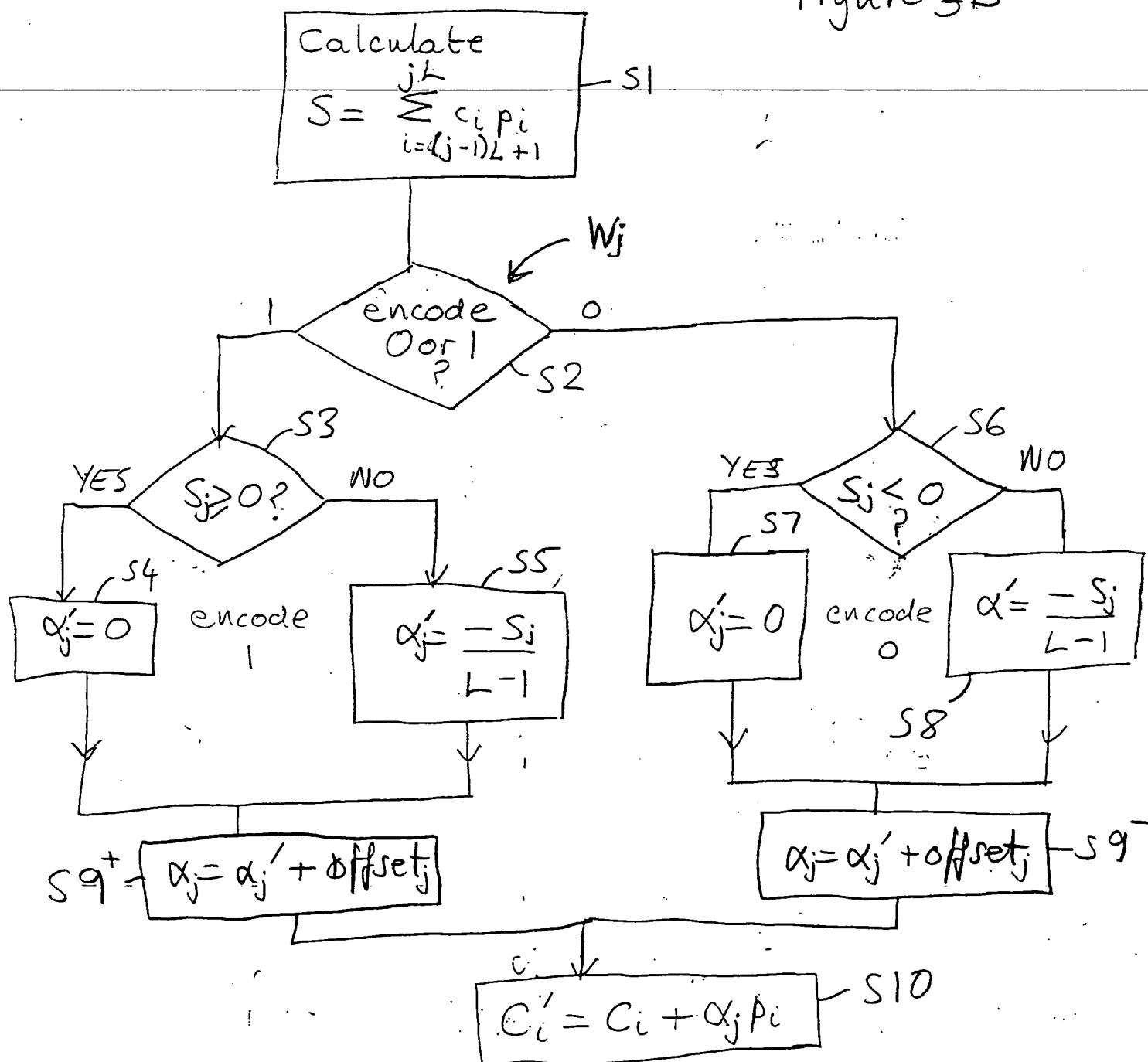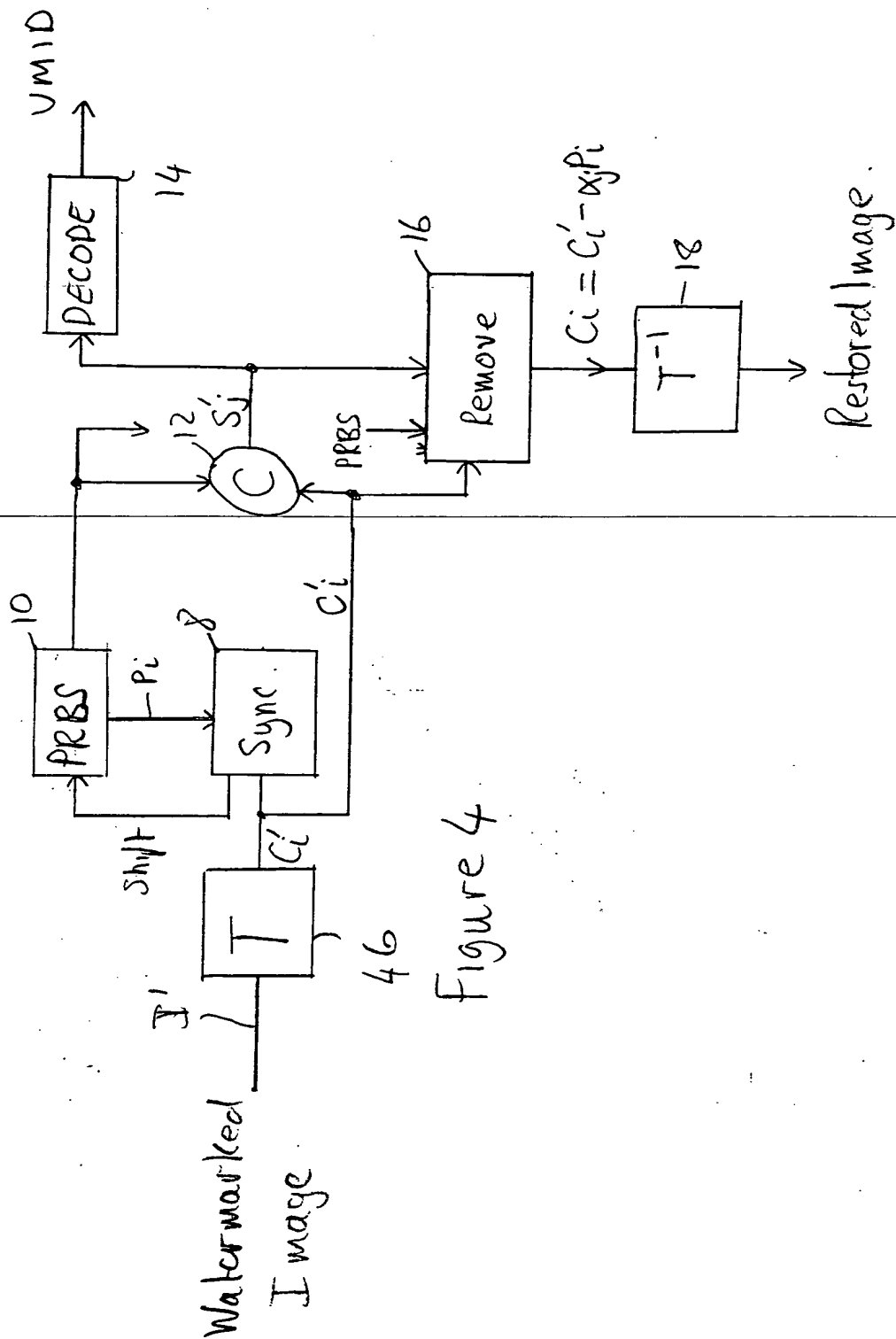
Figure 1

I-00-81

Figure 2

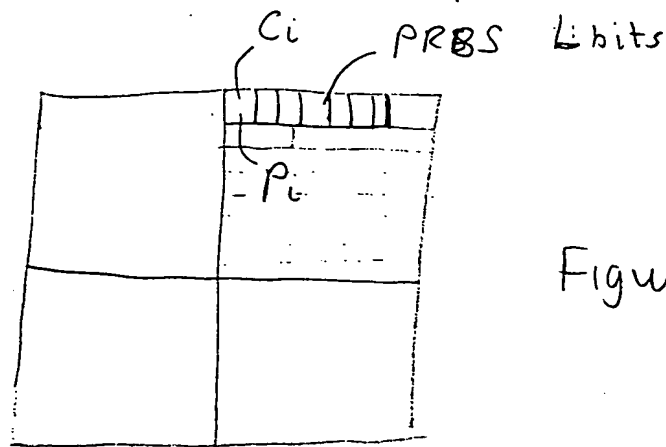$$C_i' = C_i + \alpha_j P_i$$

C_i PRBS Lbits

$-P_i$

Figure 3A

Figure 3B

Embedder

Calculate
$$S = \sum_{i=(j-1)L+1}^{jL} c_i p_i$$ S1

W_j

encode
0 or 1
?   S2

1 0

S3

YES $S_j \geq 0$?   NO

S4   encode
1   S5

$\alpha_j' = 0$ $\alpha_j' = \dfrac{-S_j}{L-1}$

S6   NO

YES $S_j < 0$
?

S7   encode
0   S8

$\alpha_j' = 0$ $\alpha_j' = \dfrac{-S_j}{L-1}$

$S9^+$ $\alpha_j = \alpha_j' + \text{offset}_j$

$\alpha_j = \alpha_j' + \text{offset}_j$ S9$^-$

$C_i' = C_i + \alpha_j p_i$ S10

Figure 4

Remover and Decoder

S12

Synchronise

S14

Correlate:
$$S_j' = \sum_{i=(j-1)L+1}^{jL} c_i' p_i$$

S16

S_j' +or-? + +ve

-tive

'0'   '1'

Calculate α'
$$\alpha_j' = \frac{S_j'}{L-1}$$

S18

Wj

UMID

Remove Watermark
$$c_i = c_i' - \alpha_j' p_i$$

S22

Source Image

Figure 5

Figure 6

Embed

Figure 8

$$C_i' = C_i + \alpha_{t+n,j} R_i$$
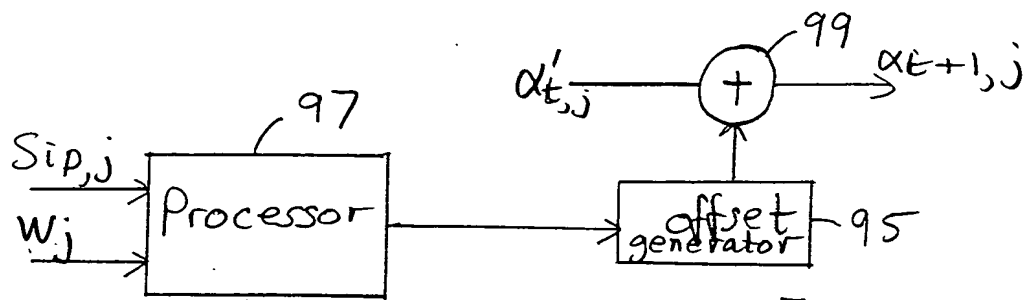
Ri
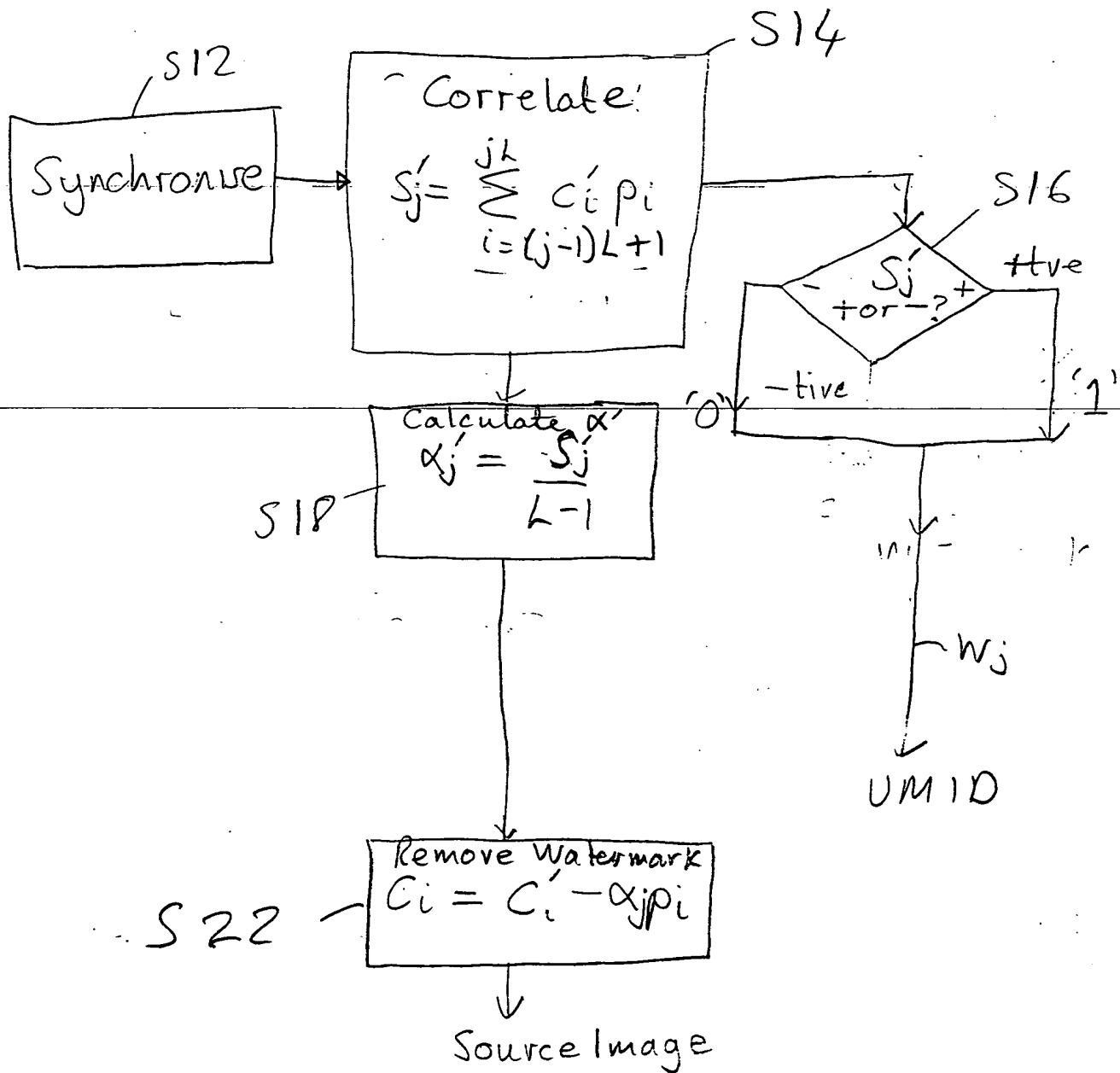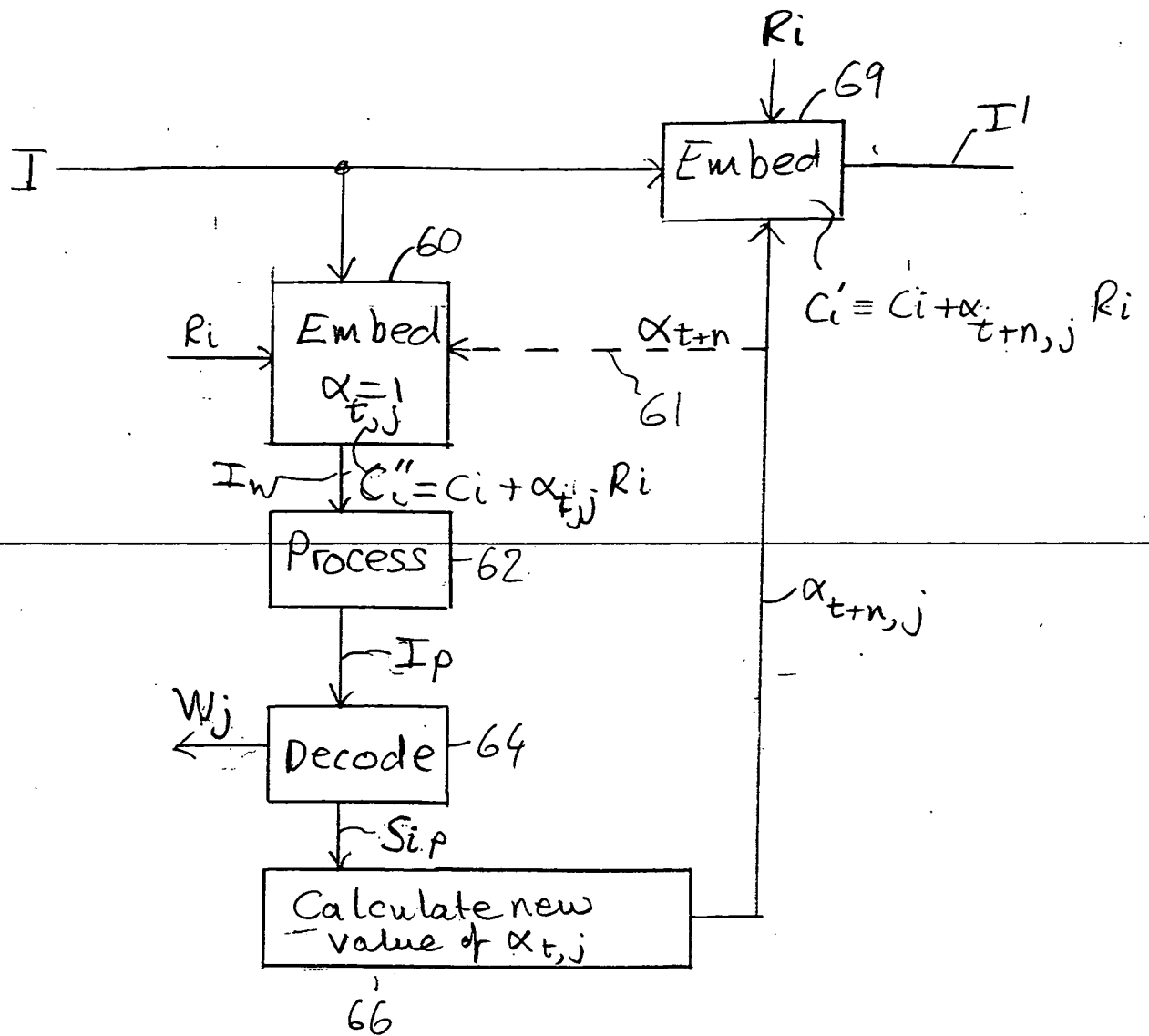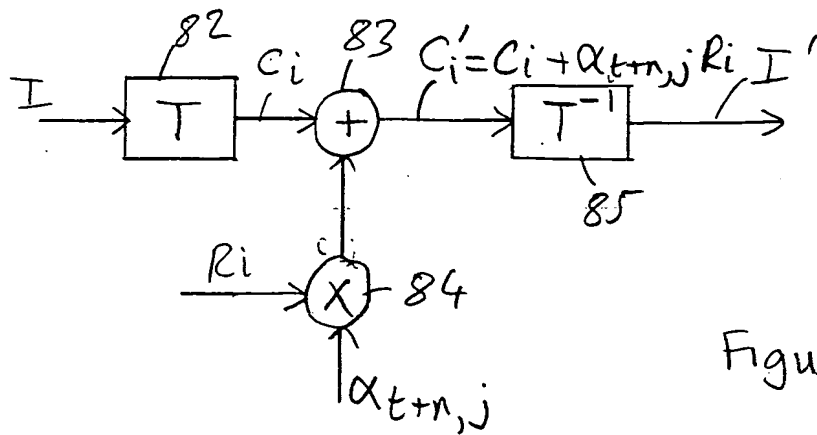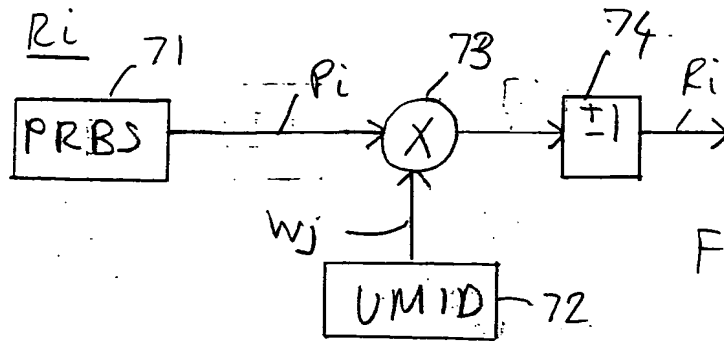
Figure 7

Decode

Figure 9.

$$S_{ip} = \sum C_{ip} \cdot P_i$$
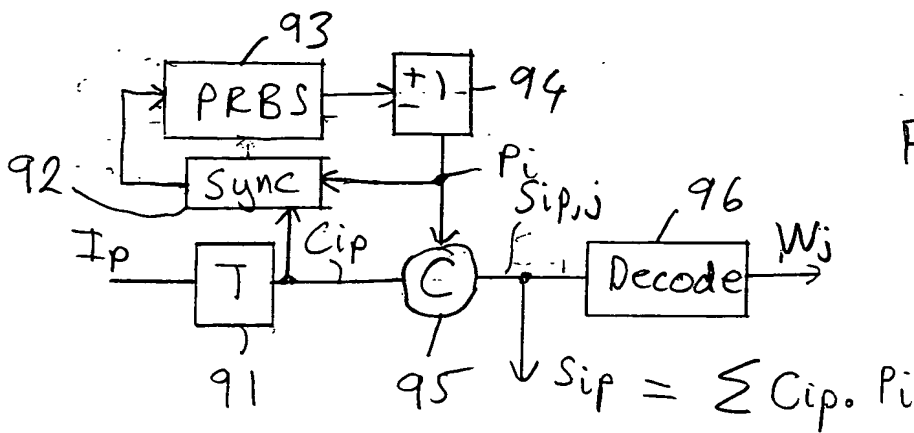
Figure 10A

Figure 10B

Figure 10C

9/10 ——— H ⟶

Spatial Domain Image ⟶ Wavelet Domain level 1

| lH_1 lV_1 | hM_1 lV_1 |
| lH_1 hV_1 | hM_1 hV_1 |

l = lowpass
h = high pass

Figure 11

Level 2

lH_2 lV_2	hM_2 lV_2	hM_1 lV_1
lH_2 hV_2	hM_2 hV_2	
lH_1 hV_1	hM_1 hV_1	

Figure 12

Image — $\div 2$ —
  HP hH
  LP lH Level 1
    $\div 2$ —
      HP' hlH
      LP' llM Level 2
        $\div 2$ —
          HP''' $hllM$
          LP''' $lllM$ Level 3
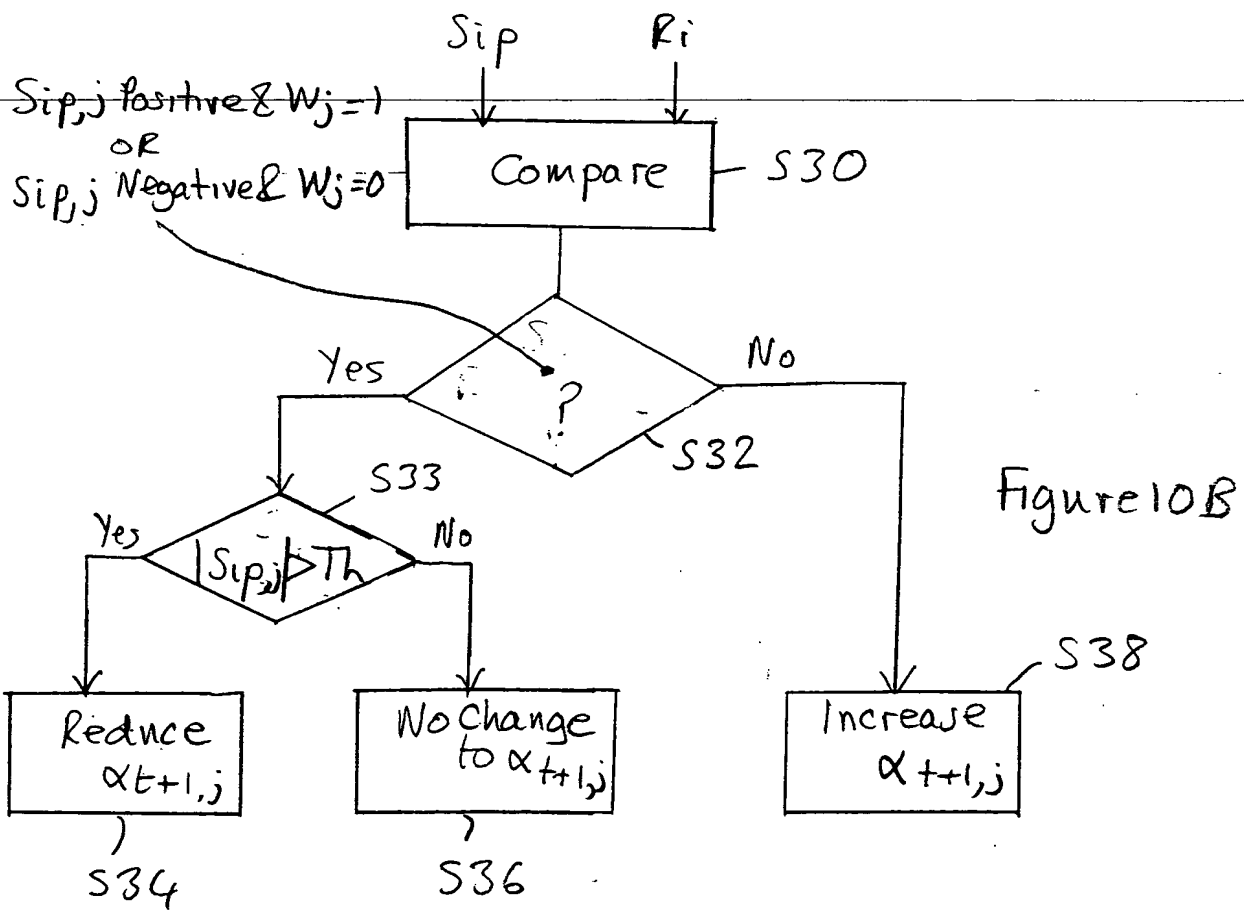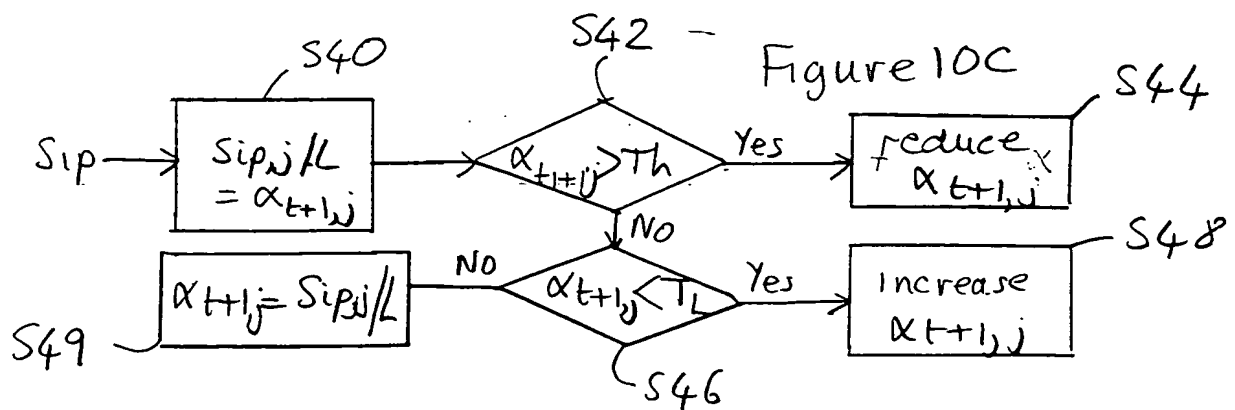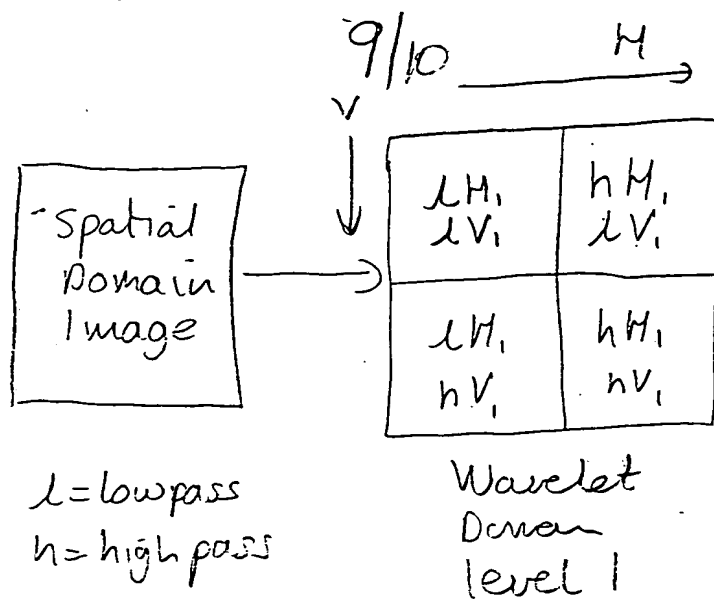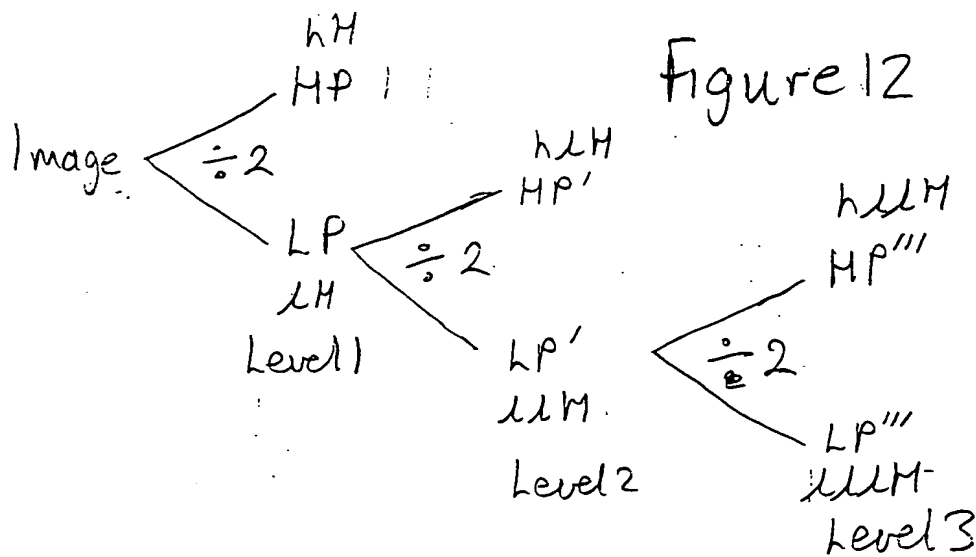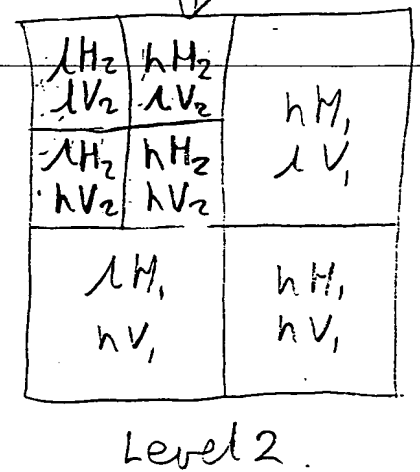
Schematic of Wavelet Transform.

I-00-81

Basic UMID (32 bytes)

Extended UMID (64 bytes)

Signature Metadata (32 bytes)

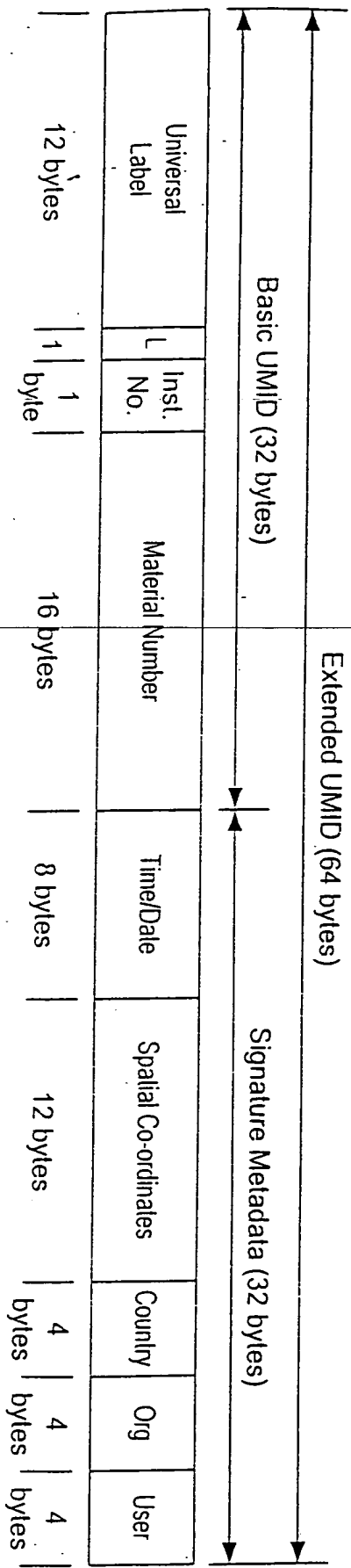| Universal Label	L	Inst. No.	Material Number	Time/Date	Spatial Co-ordinates	Country	Org	User
	L							

12 bytes | 1 byte | 1 | 16 bytes | 8 bytes | 12 bytes | 4 bytes | 4 bytes | 4 bytes

Fig. 13

Basic and Extended UMID Structures.

Type	L	B11	B12	Instance	Material
	1	1	1	3	16

Signature Metadata

32

Fig. 14